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<p>(54) Title: DIRECTED HUMAN IMMUNE GLOBULIN FOR THE PREVENTION AND TREATMENT OF STAPHYLO- COCCAL INFECTIONS  (57) Abstract  This invention is directed to a Directed Human Immunoglobulin and compositions thereof for preventing or treating sta- phylococcal infections such as <i>S. epidermidis</i>.</p>		

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1     DIRECTED HUMAN IMMUNE GLOBULIN FOR THE PREVENTION  
2     AND TREATMENT OF STAPHYLOCOCCAL INFECTIONS

3                     I. GOVERNMENT INTEREST

4                     The invention described herein may be manufactured, licensed  
5     and used by or for governmental purposes without the payment of any royalties  
6     to us thereon.

7                     II. FIELD OF THE INVENTION

8                     This invention relates to Directed Human Immune Globulin for  
9     the prevention and treatment of staphylococcal infections.

10                    III. BACKGROUND OF THE INVENTION

11                    Over the last two decades, staphylococci have become important  
12     causes of infection in hospitalized patients. Because of their high prevalence  
13     on the skin, staphylococci are ideally situated to cause serious infections in  
14     debilitated or immunosuppressed patients. The staphylococcal species most  
15     frequently pathogenic in humans are Staphylococcus aureus (SA) and  
16     Staphylococcus epidermidis (SE). Both groups have developed resistance to  
17     multiple antibiotics making antimicrobial therapy difficult. In recent years SE  
18     has become a major cause of nosocomial infection in patients whose treatments  
19     include the placement of foreign materials such as cerebrospinal fluid shunts,

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1     vascular catheters or joint prostheses. SE is a common cause of post operative  
2     wound infections peritonitis in patients with continuous ambulatory peritoneal  
3     dialysis. Patients with impaired immunity (malignancy, bone marrow  
4     transplant) or those receiving parenteral nutrition through central venous  
5     catheter are also at high risk for developing SE sepsis (Patrick, J. Pediatr.,  
6     1990).

7                 SE has emerged as a common cause of neonatal nosocomial  
8     sepsis in premature infants. As shown by Fleer and colleagues, (Pediatr Infect  
9     Dis, 1983) SE infections frequently occur in immature babies that have  
10    received parenteral nutrition. Premature babies have impaired immunity with  
11    deficiencies in antibodies, complement and neutrophil function. Lipid infusion  
12    is now a standard ingredient of parenteral nutrition therapy in many nurseries  
13    and may further impair immunity to bacterial infection as disclosed by Fischer  
14    and colleagues (Lancet, 1980; 2:819-20). Recent studies have associated  
15    coagulase negative staphylococcal bacteria in neonates with lipid emulsion  
16    infusion (Freeman and colleagues, N. Engl. J. Med, 1990). Further studies by  
17    Fleer and colleagues (J Inf Dis, 1985) showed that neonates had low levels of  
18    opsonic antibody to SE despite the fact that the sera had clearly detectable  
19    levels of IgG antibodies to SE peptidoglycan (opsonic antibodies for  
20    staphylococcus have been considered to be directed to the peptidoglycan  
21    antigens). While these studies suggested that neonatal susceptibility to SE  
22    might be related to impaired opsonic activity, it is not clear if antibodies

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1 directed against SE are opsonic or would be capable of providing protection  
2 when given passively to neonates. Further, it is unknown whether the  
3 presence of intralipid, which further impairs phagocytosis and killing of  
4 bacteria by phagocytes, would inhibit the activity of antibody.

5 The opsonic activity of pooled human immunoglobulin for SE  
6 was studied by Clark and colleagues (J Med Microbiol, 1986), and showed that  
7 complement and IgG were both critical for efficient opsonization of SE. They  
8 noted, however, that in some studies complement was not required and that  
9 contrary to the report of Fleer (1985), absorption of serum with peptidoglycan  
10 may remove the opsonic activity for SE. Further studies by Clark and Easmon  
11 (1986) showed that several lots of standard intravenous immune globulin  
12 (IVIG) had variable opsonic activity for SE. One third of the IVIG lots had  
13 poor opsonization with complement and only 2 of 14 were opsonic without  
14 complement. Despite the fact that the IVIG lots are made from large plasma  
15 donor pools good opsonic antibody to SE was not uniformly present. Their  
16 studies focused on potential use of immunoglobulin to boost peritoneal defenses  
17 in patients receiving continuous ambulatory peritoneal dialysis and did not  
18 examine whether IVIG could be utilized for the prevention or treatment of  
19 bacterial sepsis, or the use of antibody to prevent or treat sepsis and lethal  
20 infection in immature or immunosuppressed patients and Specifically, no in  
21 vivo studies were done to test antibody to prevent or treat

1 SE. There is no evidence therefore that the antibody would provide beneficial  
2 therapy in a setting of immaturity or impaired immunity.

3 The opsonic assays, that are currently used are slow and  
4 cumbersome for screening blood, plasma or immune globulin for antibodies to  
5 SE. It would be important to have a rapid antigen binding assay to screen for  
6 SE antibody, if that assay further correlated with opsonic activity in vitro and  
7 protection in vivo.

8 In order to determine if IgG is capable of enhancing protection  
9 against SE, a suitable animal model that is comparable to patients with SE  
10 infections is required. This is critical since neonates have low levels of  
11 complement and impaired neutrophil and macrophage function. While opsonic  
12 activity of immune globulin may be adequate under optimal conditions in vitro,  
13 protection may not occur in patients with immature or impaired immune  
14 systems. As has been demonstrated by Clark and colleagues (J Clin Pathol,  
15 1986), most IVIG preparations were not opsonic when complement was  
16 removed. However, since SE has low virulence, suitable animal models of SE  
17 sepsis have not been available.

18 Yoshida and colleagues, (J Microbiol, 1976) reported on a  
19 virulent strain of SE that infected mature mice with 90 - 100% of mice dying  
20 within 24 - 48 hours. This model is very different from that seen in patients  
21 and may represent an unusual type of SE infection. When they analyzed 80  
22 fresh isolates of SE from humans, they were not able to kill mice. Non-human

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1 antibody to a new SE surface polysaccharide protected the mice from the  
2 virulent SE strain. A later report by Yoshida and colleagues (J Med  
3 Microbiol, 1977) confirmed their previous observations. Passive prophylaxis  
4 with immunization induced non-human antibody showed that the IgG fraction  
5 did not protect while the IgM fraction did provide protection. Thus  
6 demonstrating in this model that IgG antibody was not protective. As noted  
7 previously herein neonates had good levels of IgG to SE, but had low levels of  
8 opsonic antibody (Fleer and colleagues, J. Infect. Dis, 1985), consistent with  
9 the findings in this study and showing that the role of IgG in protection against  
10 SE is unclear. In 1987 the report by Ichiman and colleagues (J Appl Bacteriol,  
11 1987) extended their animal studies to include analysis of protective antibodies  
12 in human serum against their selected virulent strains of SE. Protective  
13 antibody was found in the IgA, IgM and IgG immunoglobulin fractions. These  
14 studies are in conflict with their previous data showing that IgG was not  
15 protective and fails to establish a definitive role for any of the immunoglobulin  
16 classes (IgG, IgM or IgA).

17 In the animal model described by Yoshida, Ichiman and  
18 colleagues mature, non-immunosuppressed mice were used and death was  
19 considered to be related to toxins not sepsis (Yoshida and colleagues, J.  
20 Microbiol, 1976). Most clinical isolates did not cause lethal infections in their  
21 model. Since quantitative blood cultures were not done, it is not known  
22 whether antibody would prevent or treat SE sepsis in immature



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1 immunosuppressed patients or specifically in the presence of intralipid.

2           Antibody provides protection in humans against certain

3 encapsulated bacteria such as Hemophilus influenzae and Streptococcus

4 pneumoniae. Individuals such as young infants who are deficient in antibody

5 are susceptible to infections with these bacteria and bacteremia and sepsis are

6 common. When antibody to these bacteria is present it provides protection by

7 promoting clearance of the bacteria from the blood. Immunoglobulin with

8 antibody to H. influenzae and S. pneumoniae protects infants from sepsis with

9 these bacteria. The article by Espersen and colleagues, (Arch Intern Med,

10 1987) discloses the use of an antigen binding RIA assay to analyze IgG

11 antibody to SE in patients with uncomplicated bacteremia and those with

12 bacteremia and endocarditis. This assay used an ultrasonic extract of SE to

13 identify SE specific IgG (the surface antigen in this study differs from the

14 antigen used by Yoshida and colleagues which was obtained by a different

15 method; gentle sonic oscillation). None of the patients with uncomplicated

16 bacteremia had IgG antibodies to SE. These data would suggest that IgG is

17 unnecessary for effective eradication of SE from the blood. In addition, 89%

18 of bacteremic patients with endocarditis developed high levels of IgG to SE.

19 In these patients, IgG was not protective since high levels of IgG antibody

20 (which may have developed late) were associated with serious bacteremia and

21 endocarditis. Based on these studies the protective role of IgG in SE sepsis

22 and endocarditis is not established, especially in the presence of immaturity,

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1 debilitation, intralipid infusion, or immunosuppression. In addition, the  
2 extensive review of Patrick et al. (J. Pediat., 1990) does not include  
3 immunoglobulin as a potential prophylactic or therapeutic agent for SE  
4 infections.

5 It has been recognized by the medical community that SE is an  
6 important pathogen in certain high risk individuals, such as patients with  
7 foreign body implants, premature neonates and immunosuppressed patients.  
8 Accordingly there is a need for a human immune globulin that would prevent  
9 or treat SE infections such as, sepsis or endocarditis and promote clearance of  
10 SE from the blood of such high risk people.

#### 11 IV. SUMMARY OF THE INVENTION

12 It is therefore an object of the present invention to provide a  
13 novel Directed Human Immune Globulin for preventing or treating  
14 staphylococcal infections. We have found that it is useful to screen serum  
15 (plasma) or pooled immunoglobulin for specific antibody to S. epidermidis to  
16 produce Directed Human Immune Globulin to this pathogen. This Directed  
17 Human Immune Globulin is different from standard human immune globulin  
18 preparations in that it has high levels of human anti-staphylococcal antibodies  
19 that react with surface antigens of S. epidermidis and enhance phagocytosis  
20 and killing of S. epidermidis in vitro, (opsonophagocytic bactericidal activity  
21 greater than 80%). In addition, Directed Human Immune Globulin for S.

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1 epidermidis enhances immunity in vivo and prevents lethal infection as well as  
2 enhancing clearance of S. epidermidis from the blood in conditions of  
3 immaturity and impaired immunity. This is surprising since  
4 immunosuppression or immaturity would be expected to render the antibody  
5 ineffective by impairing the ability of phagocytic cells to engulf and kill the S.  
6 epidermidis.

7 It is also another advantageous object of the present invention  
8 that while standard immunoglobulin pools or normal donors do not have  
9 reliable levels of opsonic antibody for S. epidermidis, Directed Human  
10 Immune Globulin when given intravenously immediately provides specific  
11 antibodies to promote phagocytosis and killing of S. epidermidis by  
12 phagocytes. A further advantages of the present invention is that by providing  
13 opsonic antibody to immature or immunosuppressed patients infected with SE,  
14 antibiotic therapy may be enhanced by improved S. epidermidis clearance from  
15 the blood or site of infection. Another advantage is that since Directed Human  
16 Immune Globulin given intravenously or intramuscularly can raise the level of  
17 antibodies in the blood of patients, Directed Human Immune Globulin could  
18 prevent S. epidermidis from causing bacteremia and local infections.

19 The method of producing the Directed Human Immune Globulin  
20 for S. epidermidis involves:

21 a) screening plasma (pools of immunoglobulin or plasma;  
22 immunoglobulin or immunoglobulin preparations) for antibodies to S.

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1 epidermidis using an in vitro antigen-binding assay: (ELISA), followed by  
2 confirmation of functional activity using an in vitro opsonophagocytic  
3 bactericidal assay (bactericidal activity greater than 80%).

4 b) Protective efficacy can be documented in vivo by  
5 analyzing protective activity of the Directed Human Immune Globulin using a  
6 suckling rat model of neonatal S. epidermidis sepsis (mortality and bacterial  
7 clearance). We believe that this is the first in vivo model to test antibody  
8 effectiveness in the presence of immaturity and/or intralipid induced immune  
9 suppression.

10 These methods could be repeated using other staphylococci such as SA  
11 instead of SE to produce Directed Human Immune Globulin for S. aureus.

12 This novel Directed Human Immune Globulin for SE could be used to  
13 prevent lethal SE infections in high risk patients such as neonates and adults in  
14 intensive care units or patients with in-dwelling foreign bodies such as venous  
15 and arterial catheters or ventricular shunts. Directed Human Immune Globulin  
16 could also be used in addition to antibiotics as adjunctive therapy to enhance  
17 bacterial clearance in patients treated for SE infections.

18 Other objects, features and advantages of the present invention will  
19 become apparent from the following detailed description. It should be  
20 understood, however, that the detailed description and specific examples, while  
21 indicating preferred embodiments of the invention, are given by way of  
22 illustration only, since various changes and modifications within the spirit and

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1 scope of the invention will become apparent to those skilled in the art from  
2 this detailed description.

3 The terms Standard Human Immunoglobulin and Directed  
4 Human Immune Globulin for S. epidermidis as used in this application are  
5 defined as follows: Standard Human Immunoglobulin - immune human  
6 globulin that was prepared by pooling immunoglobulin from many donors,  
7 without selecting donors or screening the immunoglobulin to ensure antibody  
8 activity for S. Epidermidis.

9 Directed Human Immune Globulin for S. epidermidis - Immune  
10 globulin prepared by screening for antibody to S. epidermidis (Bactericidal  
11 Activity > 80%), thereby providing a human immune globulin with protective  
12 levels of antibody to S. epidermidis and suitable for preventing or treating S.  
13 epidermidis infections. Bactericidal Activity-The percentage of bacteria killed  
14 with the addition of antibody, using a neutrophil mediated opsonophagocytic  
15 bactericidal assay after 2 hours of incubation at 37°C.

16 V. BRIEF DESCRIPTION OF THE DRAWINGS

17 Figure 1

18 Figure 1 shows that when several pools of human standard intravenous  
19 immunoglobulin were analyzed, there was a marked difference in the antibody  
20 activity to S. epidermidis as measured by an antigen binding assay (ELISA,

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1 highest O.O. reading at 1 1/2 hrs using 1:100 Dil). These were large pools of  
2 IgG, purified by several companies using various techniques. Of three pools  
3 with the highest titers, two were from Cutter Laboratories, Berkeley  
4 California, (40P07, 40R09) and one was from Sandoz, East Hanover, N.J.  
5 (069). One preparation from Cutter also had next to the lowest activity  
6 (2801). These data show that standard unscreened human immunoglobulin has  
7 variable levels of antibody to S. epidermidis and that no single method used to  
8 prepare the immunoglobulin or utilizing a large donor pool size will ensure  
9 good antibody activity to S. epidermidis. In addition, a donor was shown to  
10 have high antibody activity (Sam) to S. epidermidis demonstrating the  
11 feasibility of identifying units of plasma or, plasma donors with high levels of  
12 antibodies to staphylococcus.

13 Figure 2

14 Figure 2 shows that using an in vitro functional (opsonic) assay that  
15 measures the ability of immunoglobulin to promote phagocytosis and killing of  
16 S. epidermidis by neutrophils in the presence of complement, that opsonic  
17 activity is also variable in various lots and preparations of standard human  
18 immunoglobulin. The figure also shows that the immunoglobulins identified  
19 by ELISA as having high levels of antibody to S. epidermidis also had high  
20 levels of functional antibody in vitro. This is critical since this study shows  
21 that IgG that binds to TCA extracted S. epidermidis antigen will promote

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1 phagocytosis and killing of S. epidermidis. Therefore, using in vitro screening  
2 assays, one could select a Directed Human Immune Globulin for S.  
3 epidermidis that would have reliable levels of antibody to prevent or treat S.  
4 epidermidis infections.

5 It also shows that unscreened immune globulin would not  
6 provide reliable protection, since many standard human immunoglobulin lots  
7 have little or no opsonic activity for S. epidermidis. Hence, standard human  
8 immune globulin would not ensure uniformly high levels of antibody to SE and  
9 would not be uniformly protective despite the fact that large numbers of donors  
10 might be expected to provide good levels of antibody to a common bacteria  
11 such as S. epidermidis.

12 Figure 3

13 Figure 3 shows that Directed Immune Globulin protects animals from  
14 developing prolonged S. epidermidis bacteremia while standard immune  
15 globulin did not. Animals treated with Directed Immune Globulin had lower  
16 peak bacteremia levels ( $9.2 \times 10^2$  vs.  $6.5 \times 10^3$ ) and cleared the bacteremia  
17 more efficiently (at 72 hours, 5 bact. per ml vs. 380 bact. per ml; geometric  
18 mean level). In addition 72 hours after infection, 18/24 (75%) animals given  
19 Directed Immune Globulin had cleared their bacteremia and 100% survived,  
20 while only 4/20 (20%) animals given standard immune globulin died and only  
21 1/16 (6%) cleared their bacteremia during that 72 hour period. In addition to

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1 prevention, since Directed Immune Globulin enhanced S. epidermidis  
2 clearance, it would be a valuable adjunct to antibiotic therapy for people  
3 infected with S. epidermidis, since many of these patients have impaired  
4 immunity and may not clear the bacteria efficiently.

5 VI. DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

6 EXAMPLES

7 The herein offered examples provide methods for illustrating, without any  
8 implied limitation, the practice of this invention in the production of Directed  
9 Human Immune Globulin for Staphylococcus epidermidis and the use of said  
10 Immune Globulin for the prevention or treatment of infections caused by  
11 Staphylococcus epidermidis.

12 The profile of the representative experiments have been chosen  
13 to illustrate methods for producing Directed Human Immune Globulin to S.  
14 epidermidis and to demonstrate its usefulness to prevent or treat S. epidermidis  
15 infections.

16 Materials and Methods

17 Staphylococcal Strains: Although any S. epidermidis strains  
18 could be used, in these experiments we used two strains from the American



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1 Type Culture Collection, Rockville, MD (ATCC #31432 and ATCC #35984).  
2 A clinical isolate (Hay) from the blood of a child with S. epidermidis sepsis  
3 was also used and is also on deposit at the American Type Culture Collection.

4 Materials and Methods

5 Immunoglobulin: Standard Intravenous Immunoglobulin was  
6 used in these experiments to represent large immunoglobulin pools.  
7 Preparations from several companies were analyzed for comparison, to include  
8 Gamimmune, Cutter Laboratories Inc. Berkeley, California; Sandoglobulin,  
9 Sandoz, East Hanover, N.J.; Gammagard, Hyland, Los Angeles, California.  
10 Serum from individual donors were also analyzed for antibody activity to S.  
11 epidermidis.

12 Trichloroacetic Acid (TCA) Antigen Extraction

13 Staphylococcus epidermidis strains (ATCC #35984, ATCC  
14 #31432 and Hay) were grown to log phase at 37°C in 1000 ml of Tryptic Soy  
15 Broth (Difco). The bacteria were then centrifuged at 2500 RPM for 10  
16 minutes and the supernatant was aspirated and discarded. The bacterial button  
17 was resuspended in 200 ml of 2% trichloroacetic acid (TCA) and stirred  
18 overnight at 4°C. The mixture was then centrifuged at 2500 RPM for 10  
19 minutes and the supernatant aspirated. To the supernatant, 4 volumes of  
20 absolute ethanol were added and refrigerated overnight at 4°C. After  
21 centrifugation at 2500 RPM for 10 minutes, the supernatant was removed and

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1 discarded. Then, five milliliters of normal saline was added to the antigen  
2 precipitate, it was cultured to ensure sterility and then lyophilized for storage.

### 3 Antigen Binding Studies Using Enzyme-Linked

#### 4 Immunoabsorbent Assay (ELISA)

5 S. epidermidis Antigen was dissolved in carbonate buffer at a  
6 concentration of 25 micrograms/ml. To each well of A 96-well flat-bottomed  
7 microtiter plate (NUNC, Roskilde, Denmark) 100 microliters were added and  
8 stored at 4°C until used. Immunoglobulin was diluted to 1% and 2-fold  
9 dilutions prepared in phosphate-buffered saline-Tween . To each well was  
10 added 100 microliters of the serial dilutions and the plates were incubated for 1  
11 hour at 4°C. The plates were washed four times with H<sub>2</sub>O-Tween , Alkaline  
12 phosphatase linked goat anti-Human IgG (100 microliters;1:250) was added,  
13 the plates were incubated for 1 hour at 4°C and then washed H<sub>2</sub>O-Tween and  
14 100 microliters of P-nitrophenyl phosphate substrate in diethanolamine buffer  
15 were added. After 90 minutes of incubation at room temperature, the color  
16 development was determined by absorbance at 405 nm.

#### 17 Opsonic Assay:

18 To determine the functional antibody to S. epidermidis in the  
19 immune globulin pools and sera, a neutrophil mediated bactericidal assay was

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1 used. Neutrophils were isolated from adult venous blood by dextran  
2 sedimentation and ficall-hypaque density centrifugation. Utilizing a microtiter  
3 plate assay that requires a total volume of 0.1 ml/well, washed neutrophils  
4 (approximately  $10^6$  cells) were added to round-bottomed microtiter wells along  
5 with  $3 \times 10^4$  approximately mid-log phase bacteria. Newborn rabbit serum (10  
6 microliters; screened to assure absence of antibody to S. epidermidis) was  
7 used as a source of active complement. Forty microliters of 5% standard  
8 immune globulin (or serum) was added and the microtiter plates were  
9 incubated at 37°C with constant, vigorous shaking. Samples (10 microliters)  
10 were taken from each well at zero time and after 2 hours of incubation,  
11 diluted, vigorously vortexed to disperse the bacteria and cultured on blood agar  
12 plates overnight at 37°C to quantitate the number of viable bacteria. Controls  
13 consisted of neutrophils alone, complement alone and neutrophils plus  
14 complement.

15 Staphylococcal Sepsis Model:

16 A suckling rat model was used to determine the in vivo activity  
17 of antibody to S. epidermidis. Wistar rats (2 days old) were given 0.2 ml of  
18 20% Intralipid (Cutter, Berkeley California,) intraperitoneally at 0800 and  
19 1400. At three days of age each animal was again given, 0.2 ml of 20%  
20 intralipid at 0800 and 1400 and 0.2 ml of 5% immunoglobulin or serum was  
21 given IP. Shortly after the last dose of intralipid, 0.05ml (approx.  $5 \times 10^7$ )

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1 mid log phase S. epidermidis were injected subcutaneously just cephalad to the  
2 tail. Suckling rats less than 24 hours old also develop lethal S. epidermidis  
3 sepsis when infected with  $10^7$ - $10^8$  S. epidermidis subcutaneously. To analyze  
4 bacteremia levels in selected animals, 0.01 ml of blood was obtained from the  
5 tails of the suckling rats, 24, 48, and 72 hours after infection. The blood was  
6 collected under sterile conditions in micropipettes and serially diluted in  
7 Tryptic Soy Broth (Difco). Bacteria were subcultured onto plates to ensure S.  
8 epidermidis bacteremia and all animals were followed five days to determine  
9 survival.

#### 10 Results

#### 11 Antigen Binding Activity of Human Immunoglobulin for S. 12 epidermidis.

13 The results of the ELISA testing of several standard  
14 immunoglobulin preparations for antibody to S. epidermidis are presented in  
15 Figure 1. Most standard immune globulins contained low levels of antibody to  
16 S. epidermidis. However, by screening for antibody to TCA extracted antigens  
17 of S. epidermidis, some immunoglobulin lots and serum from one volunteer  
18 donor were found to have increased levels of antibody to S. epidermidis (O.D.  
19 readings 1.014, 1.026, and 1.002). Variations in antibody to S. epidermidis  
20 occurred between preparations prepared by different techniques and lot to lot  
21 variation in a single preparation was seen as well, indicating that all  
22 immunoglobulin pools were not the same.

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1       Opsonic Activity of Human Immunoglobulins for *S. epidermidis*.

2               All antibody directed against a given organism may not enhance  
3 immunity and provide enhanced protection from infection. Stated differently,  
4 antibodies can bind to bacteria and yet not enhance opsonization in vitro or  
5 clearance from the blood of an infected host. Therefore a functional assay was  
6 also utilized to determine if the antibody to *S. epidermidis* detected by ELISA  
7 was also capable of promoting phagocytosis and killing of the organism by  
8 neutrophils (Figure 2). Opsonic antibody activity ranged from low (<25%  
9 bactericidal activity), to moderate activity (25-80%) and a few had high  
10 bactericidal activity (>80%). Therefore two standard human immune globulin  
11 preparations with high bactericidal activity were selected as Directed Human  
12 Immune Globulin for *S. epidermidis* based on in vitro assays that measured  
13 antibody binding to TCA *S. epidermidis* antigens and opsonic antibody activity  
14 determined by in vitro testing. Serum from a single donor also had good  
15 opsonic activity for *S. epidermidis* (>80% opsonophagocytic bactericidal  
16 activity). While serum and plasma from several individuals have been studied  
17 only this donor had high opsonic activity. Therefore donor screening could  
18 detect individual blood or plasma donors that could contribute immunoglobulin  
19 that could be pooled as an alternate method to produce a

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1 Directed Human Immune Globulin for S. epidermidis. In addition blood or  
2 plasma units could be screened for pooling as well.

3 Animal Protection Studies

4 Description of Tables

5 Table 1

6 Table 1 shows the effect of Directed Human Immunoglobulin for  
7 S. epidermidis (40R09) (which was selected by ELISA and opsonic assay  
8 screening) compared to standard human immunoglobulin (that had moderate  
9 activity for S. epidermidis) and saline control. Table 1 shows that untreated  
10 control animals had about a 50% mortality while animals given Directed  
11 Immune Globulin for S. epidermidis were fully protected (NO mortality).  
12 Standard immune globulin gave only partial protection. Other standard  
13 immune globulin lots with lower levels of antibody to S. epidermidis would be  
14 even less effective, since mortality was much higher with saline. However,  
15 one would not expect that Directed Immune Globulin would be always 100%  
16 effective, but that it would consistently improve survival over standard immune  
17 globulin or untreated animals.

18 Table 2

19 Table 2 demonstrates that Directed Immune Globulin produced  
20 in rabbits by immunization (S. epidermidis vaccine) produced survival similar

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1 to Directed Human Immune Globulin produced by screening immunoglobulin  
2 for antibody to S. epidermidis. Immunization of individuals with S.  
3 epidermidis vaccine and collecting plasma for immunoglobulin extraction  
4 would be another method for producing Directed Human Immune Globulin for  
5 preventing or treating S. epidermidis infections.

6 Table 3

7 Table 3 shows that intralipid causes a dose related increased  
8 mortality in suckling rats infected with S. epidermidis. Control animals  
9 receiving Intralipid alone had 100% survival (43/43) while immature rats given  
10 16 gm/kg of Intralipid had only 46% survival (6/13). The high dose of  
11 Intralipid appears to impair the immune system sufficiently to allow the  
12 normally avirulent S. epidermidis to overwhelm the baby animals.

13 Table 4

14 Table 4 shows that normal 3 day old suckling rats not given  
15 Intralipid, but infected with S. epidermidis develop bacteremia. However,  
16 over 72 hrs their immune system is able to clear the organisms from the blood  
17 and all of the baby rats survive.

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1                   Table 1 shows the Directed Human Immune Globulin for S.  
2   epidermidis (selected by screening standard immunoglobulin for opsonic or  
3   antigen binding activity for S. epidermidis) provides complete protection from  
4   lethal infection in the setting of impaired immunity with Intralipid while  
5   standard immune globulin (with moderate antibody levels) had only partial  
6   protection (1 out of 5 animals died compared to about 50% with saline).  
7   Additional studies with another immunoglobulin preparation, (Alpha  
8   Pharmaceuticals; Directed Human Immune Globulin 8016A >90% opsonic  
9   activity, versus standard human immune globulin, 8007A < 50% opsonic  
10   activity) showed that the Directed Human Immune globulin also provided  
11   enhanced survival (8016A-64/95 (67%) vs. 8007A-39/90 (43%)) over standard  
12   human immune globulin. Even more striking was the fact that the Directed  
13   Human Immune Globulin decreased the peak level of S. epidermidis  
14   bacteremia and promoted rapid clearance of the bacteria (Figure 3). These  
15   studies showed that antibody was important for protection against S.  
16   epidermidis enhanced bacterial clearance from the blood and could be an  
17   effective prophylactic or therapeutic modality even in the immature host with  
18   impaired immunity. Many of the animals treated with standard human immune  
19   globulin remained bacteremic 72 hours after infection while only 1/20 animals  
20   was still bacteremic at 72 hours after receiving the Directed Human Immune  
21   Globulin. In addition the mean bacteremia level at 72 hours was



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1 markedly different (bacteremia with Directed Human Immune Globulin  $0.5 \times$   
2  $10^4$  vs. bacteremia with standard human immune globulin  $3.8 \times 10^2$ ).

3 In further studies, rabbit Directed Immune Globulin for S.  
4 epidermidis was produced by immunizing rabbits with S. epidermidis vaccine.  
5 The vaccine induced Directed Immune Globulin was compared with Directed  
6 Human Immune Globulin produced by screening immunoglobulin for antibody  
7 to S. epidermidis (Table 2). Vaccine induced Directed Immune Globulin had  
8 similar protective activity to Directed Human Immune Globulin produced by  
9 screening (9/11 vs. 12/13 survived) and each was better than controls (11/19  
10 survived). These data show that S. epidermidis vaccine induced antibody  
11 could be used for prevention and treatment of S. epidermidis infections and  
12 that vaccine could be used to produce a Directed Human Immune Globulin.

13 TABLE 3

14 Many bacteria such as S. epidermidis are not pathogenic in  
15 normal people. However, in babies with an immature immune system or  
16 impaired immunity as is seen with intralipid, S. epidermidis may cause sepsis  
17 and death. It is critical therefore, that any animal model to test antibody  
18 effectiveness should include these factors. To our knowledge this is the first  
19 time that antibody to Staphylococcus epidermis has been shown to provide  
20 protection and enhance bacterial clearance in an immature and/or

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1 immunosuppressed host. Intralipid given in dosage up to 16 gm/kg did not  
2 cause death in any baby animals (controls, table 3). In the absence of  
3 Intralipid, the 3 day old animals will become bacteremic with S. epidermidis  
4 after infection, but will clear the infection over 72 hours and survive (Table 4).  
5 However, Intralipid did impair immunity in a dose related fashion and when  
6 the 3 day old animals were infected with S. epidermidis lethal sepsis occurred  
7 in up to 67% of the animals. Baby rats in the first day of life also do not clear  
8 bacteremia well (due to immature immunity) and develop lethal sepsis. In  
9 these models baby rats were unable to clear the S. epidermidis bacteremia and  
10 developed lethal sepsis. Directed Human Immune Globulin was able to  
11 enhance survival and promote bacterial clearance while standard human  
12 immune globulin did not enhance clearance (Fig 3).

13 TABLE 4

14 When SE is injected into normal baby rats, they become  
15 bacteremic in 2 hours and then begin to slowly clear the bacteria from the  
16 blood. All of the animals cleared the bacteremia 72 hours after the infection.  
17 thus suggesting that under normal circumstances neonatal immunity while  
18 impaired can eventually control SE. However, studies in rats infectedd with S.  
19 epidermidis shortly after birth have demonstrated that they can also develop a  
20 lethal infection.

**TABLE I**  
**Effectiveness of Standard Immune Globulin**  
**and Directed Immune Globulin to**  
**Staphylococcus epidermidis in Providing Protection**  
**from lethal *S. epidermidis* Infection**  
**in a Suckling Rat Model**

Immunoglobulin Type	Treated	Died	% Mortality
Directed Immune Globulin * (40R09)	24	0	0
Standard Immune Globulin *	20	4	20%
Control			
Untreated**	13	7	54%
Uninfected**	11	0	0

\* #20-23 - 3/25/90

\*\* #8 - 2/11/90, #4 - 1/29/90

**TABLE 2**  
**Comparison of Therapeutic Efficacy of**  
**Vaccine Induced Anti-staphylococcal**  
**Directed Immune Globulin with Screened**  
**Directed Immune Globulin in a *S. epidermidis* Sepsis Model\***

Treatment	Exp.	Treated	Survived	% Survived
Vaccine Induced Directed Immune Globulin	16,19	11	9	82%
Screened Directed Immune Globulin (40R09)	17,18	13	12	92%
Saline Control	16,17 18,19	19	11	58%
* 1990 Studies				

**TABLE 3**  
**Animal Model: Effect of Intralipid Dosage on**  
**Staphylococcus epidermidis mortality in suckling rats**

<u>Intralipid</u>	<u>Survival</u>	
	<u>Infected</u>	<u>Control</u>
<u>Dose</u>		
4 gm/kg	10/10 (100%)	7/7 (100%)
8 gm/kg	10/13 (76%)	9/9 (100%)
12 gm/kg	7/12 (58%)	11/11 (100%)
16 gm/kg	6/13 (46%)	11/11 (100%)
*16 gm/kg	2/6 (33%)	5/5 (100%)

11 Infection with S. epidermidis (Haywood); approximately  $10^7$  bacteria SQ.

12 Standard model starts IL on day 2 of life with infection after last IL dose on day 3 if full 4 doses given.

13 \*IL started on day 1 of life with infection after the 4th dose on day 2.

TABLE 4

Staphylococcus epidermidis Bacteremia Levels in Normal Suckling  
Rats Given Normal Saline Instead of Intralipid

Time Post Infection	Number Bacteremic	Per Cent Bacteremic	Bacteremia Level *
2 hours	8/8	100	$3.8 \times 10^2$
4 hours	7/8	87.5	$1.3 \times 10^2$
6 hours	8/8	100	$7.5 \times 10^2$
24 hours	6/8	75	$8.8 \times 10^1$
48 hours	3/8	37.5	$0.5 \times 10^1$
72 hours	0/8	0	0
Exp. 93+94: 8/8 survived			

\*Mean number of bacterial per ml of blood

1  
2  
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1     We claim:

2                     1. A Directed Human Immune Globulin for the prevention or  
3     treatment of Staphylococcus epidermidis infections.

4                     2. A Directed Human Immune Globulin of Claim 1 which  
5     contains a measured level of anti-staphylococcal IgG antibodies that react with  
6     surface antigens of Staphylococcus epidermidis and promote phagocytosis and  
7     killing of Staphylococcus epidermidis in vitro and/or protection against  
8     Staphylococcus epidermidis in vivo.

9                     3. The Directed Human Immune Globulin of Claim 2 wherein  
10    the measured level of anti-staphylococcal IgG antibodies has an opsonic  
11    activity within the range of about 80 to about 100 percent.

12                    4. A pharmaceutical composition comprising an amount of  
13    Directed Human Immune Globulin of Claim 1 sufficient to prevent or treat  
14    infections by S. epidermidis and a pharmaceutically acceptable carrier therefor.

15                    5. A pharmaceutical composition comprising a Directed Human  
16    Immune Globulin of Claim 2.

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1                   6. A pharmaceutical composition comprising a Directed Human  
2 Immune Globulin of Claim 3.

3                   7. A method of preparing a Directed Human Immune Globulin  
4 of Claim 1 by screening serum, plasma, or an immunoglobulin pool by S.  
5 epidermidis ELISA or Opsonic Assays.

6                   8. The method of Claim 7 wherein serum is screened by S.  
7 epidermidis ELISA or Opsonic Assays.

8                   9. The method of Claim 8 wherein the serum is screened by S.  
9 epidermidis ELISA.

10                  10. The method of Claim 8 wherein the serum is screened by  
11 S. epidermidis Opsonic Assays.

12                  11. The method of Claim 7 wherein the plasma is screened by  
13 S. epidermidis ELISA or Opsonic Assays.

14                  12. The method of Claim 11 wherein the plasma is screened by  
15 S. epidermidis ELISA.



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1                   13. The method of Claim 11 wherein the plasma is screened by  
2     S. epidermidis Opsonic Assays.

3                   14. The method of Claim 7 wherein the immunoglobulin pool is  
4     screened by S. epidermidis ELISA or Opsonic Assays.

5                   15. The method of Claim 14 wherein the immunoglobulin pool  
6     is screened by S. epidermidis ELISA.

7                   16. The method of Claim 14 wherein the immunoglobulin pool  
8     is screened by S. epidermidis Opsonic Assays.

9                   17. A method of preparing a Directed Human Immune Globulin  
10    of Claim 1 comprising the steps of: (a) immunizing plasma donors and (b)  
11    removing plasma from said donors for Directed Immune Globulin preparation.

12                  18. A method of assessing the protective level of Direct  
13    Human Immune Globulin by using an immature or intralipid induced lethal  
14    model to provide minimum protective standard comprising the steps of: (a)  
15    screening with in vitro assays and (b) using animal lethality tests to ensure that  
16    the immunoglobulin preparation provided protective antibody to S.  
17    epidermidis.

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1                    19. A method of treating a host with a therapeutically- effective  
2                    amount of S. epidermidis of Directed Human Immune Globulin of Claim 1 by  
3                    intravenous administration thereof.

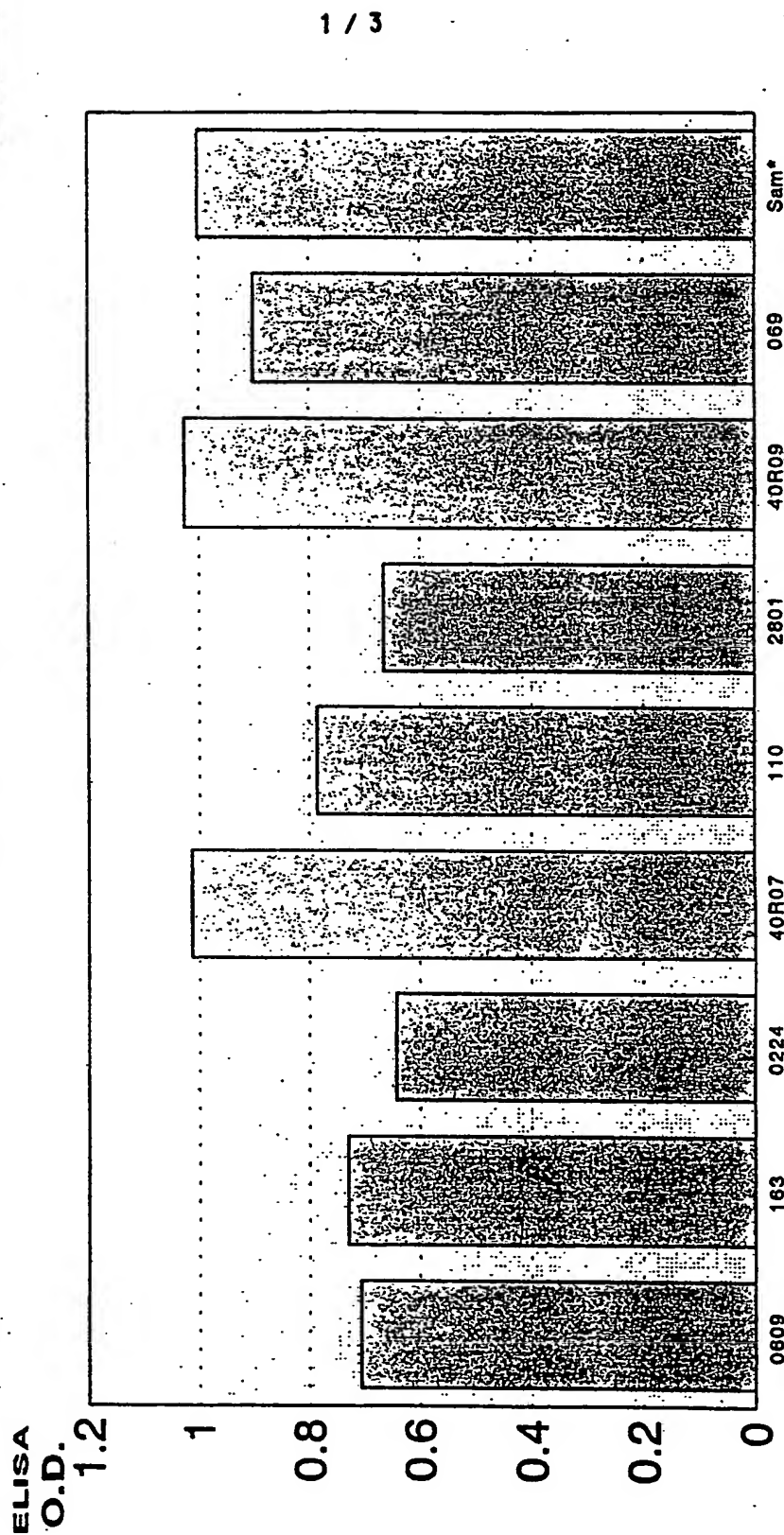
4                    20. A method of treating a host with a therapeutically effective  
5                    amount of S. epidermidis of Directed Human Immune Globulin of Claim 1 by  
6                    intramuscular administration thereof.

7                    21. The method of Claim 19 wherein the host is treated prior to  
8                    infection with S. epidermidis.

9                    22. The method of Claim 20 wherein the host is treated after  
10                    infection with S. epidermidis.

# Figure 1

## Antigen Binding Activity of Human Immunoglobulin for Staphylococcus epidermidis



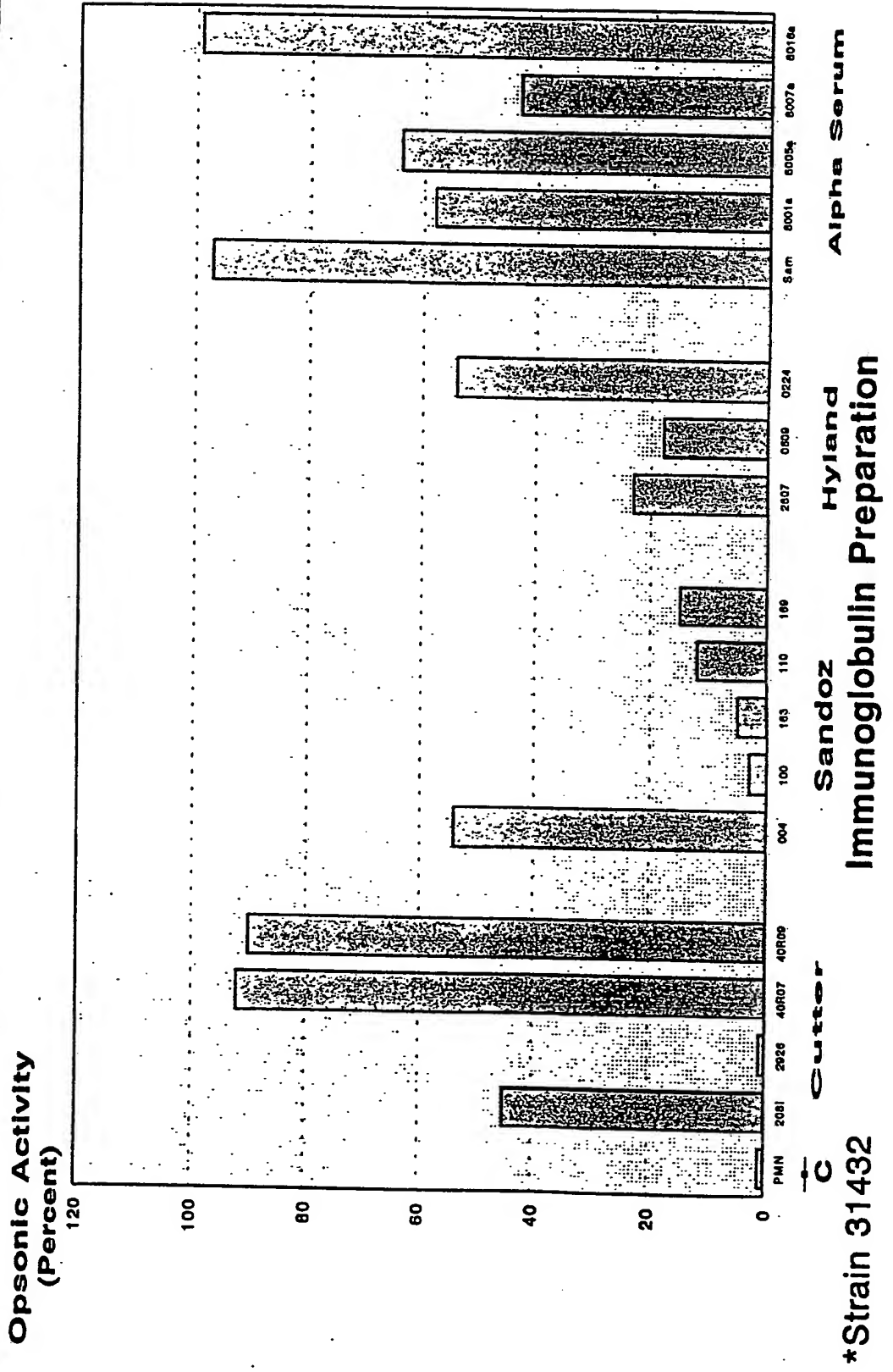
ELISA - 10/13/89  
Haywood TCA extract  
Using 1 1/2 hr. highest  
O.D. at 1:100

Immunoglobulin Pool

\*Immunoglobulin from Human donor

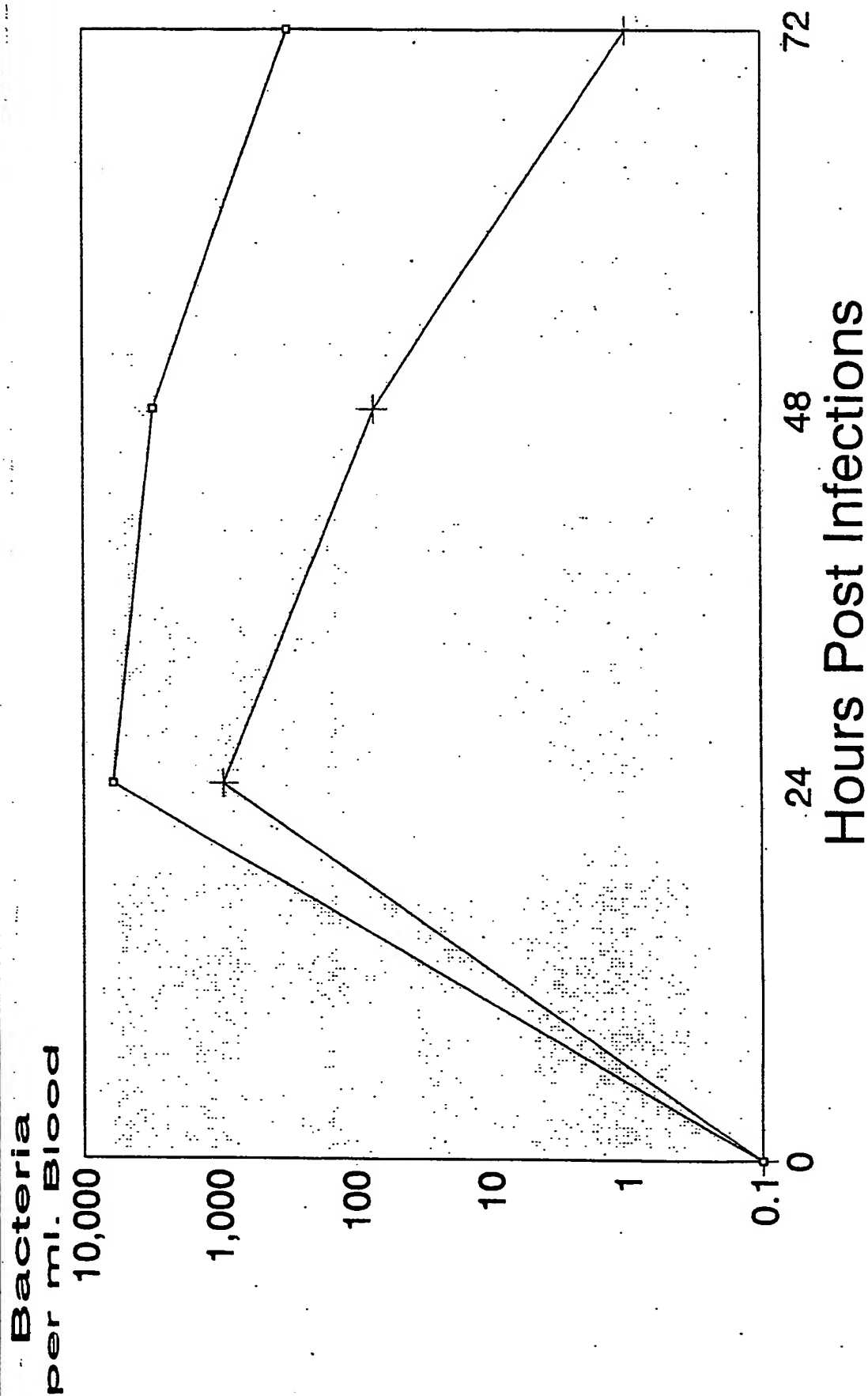
# Figure 2

Opsonic Activity of Human Immunoglobulin  
for Staphylococcus epidermidis \*



# Figure 3

Effect of Standard Immune Globulin and Directed Immune Globulin on Clearance of *S. epidermidis* from the Blood of Animals with *S. epidermidis* Se



## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US92/09830

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(5) : Please See Extra Sheet.

US CL : 530/389.5; 424/9, 87, 92; 435/7.92

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 530/389.5; 424/9, 87, 92; 435/7.92

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)  
CAS ONLINE, MEDLINE, APS

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 4,027,010 (Kiselev et al.) 31 May 1977, the Abstract.	1-6, 17
Y	US, A, 4,197,290 (Yoshida et al.) 08 April 1980, the Abstract.	1-6, 17
X Y	Journal of Applied Bacteriology, Volume 63, issued 1987, Y. Ichiman et al., "Protective antibodies in human sera against encapsulated strains of Staphylococcus epidermidis", pages 165-169, especially page 165.	1-6 1-16, 18-22
Y	Infection and Immunity, Volume 42, No. 3, issued December 1983, T. E. West et al., "Detection of anti-teichoic acid immunoglobulin G antibodies in experimental Staphylococcus epidermidis endocarditis", pages 1020-1026, especially page 1020.	1-16, 18-22
Y	Journal of Clinical Microbiology, Volume 23, No. 2, issued February 1986, F. Espersen et al., "Enzyme-linked immunosorbent assay for detection of Staphylococcus epidermidis antibody in experimental S. epidermidis endocarditis", pages 339-342, especially page 339.	1-16, 18-22

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be part of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubt on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means		
"P" document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 27 JANUARY 1993	Date of mailing of the international search report 24 FEB 1993
Name and mailing address of the ISA/ Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	Authorized officer CHRISTINA CHAN
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## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US92/09830

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	J Clin Pathol, Volume 39, issued 1986, L. Clark et al., "Opsonic activity of intravenous immunoglobulin preparations against Staphylococcus epidermidis", pages 856-860, especially page 856.	1-16, 18-22
Y	The Lancet, issued 18 October 1980, G. W. Fischer et al., "Diminished bacterial defences with intralipid", pages 819-820, especially page 819.	18
A	The New England Journal of Medicine, Volume 323 No. 5, issued 02 August 1990, J. O. Klein, "From Harmless commensal to invasive pathogen coagulase-negative Staphylococci", pages 339-340.	1-22

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US92/09830

## A. CLASSIFICATION OF SUBJECT MATTER: IPC (5):

C07K 15/06; A61K 35/16, 39/40, 39/085, 39/395, 49/00; C12Q 1/00; G01N 33/536

## BOX II. OBSERVATIONS WHERE UNITY OF INVENTION WAS LACKING

This ISA found multiple inventions as follows:

- I. Claims 1-6 and 19-22, drawn to an immune globulin, a composition, a method of preparing an immune globulin and a method of using the immune globulin, Classes 530, 435 and 424, Subclasses 389.5, 7.92 and 87, respectively.
- II. Claim 17, drawn to a method of preparing an immune globulin, Class 424, Subclass 92.
- III. Claim 18, drawn to a method of assessing the protective level of an immune globulin, Class 424, Subclass 9.

The inventions are distinct, each from the other because of the following reasons:

Inventions II and I are related as process of making and product made. In the instant case the product as claimed can be made by materially different processes such as the two different processes in Groups I and II.

Further, the inventions as grouped are distinct, each from the other, because they represent different inventive endeavors. The inventions of Groups I-II would not suggest the invention of Group III.